REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
06-03-2011

2. REPORT TYPE
Final Performance Report

3. DATES COVERED *(From - To)*
01 JUN 2009 – 31 MAY 2010

4. TITLE AND SUBTITLE
Acquisition of a scanning laser vibrometer system for experimental studies on nonparametric nonlinear system identification and aeroelastic instability suppression

5a. CONTRACT NUMBER

5b. GRANT NUMBER
FA9550-09-1-0455

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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AFOSR
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10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-OSR-VA-TR-2012-0550

12. DISTRIBUTION / AVAILABILITY STATEMENT
Unlimited-A

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The PIs' current research and development, funded by AFOSR, aims to develop novel means of vibration control for aerospace systems, system identification procedures for strongly nonlinear dynamical systems, and a fully passive limit cycle oscillation (LCO) suppression system for a model generic transport wing (GTW) previously designed, built and tested in the TDT at NASA Langley. Initial efforts by the PIs led to the development of the Nonlinear Energy Sink (NES), a completely passive nonlinear mechanical device that, when physically attached to a vibrating primary system, draws energy from that system into itself in a one-way, irreversible fashion and effectively dissipates it. Later efforts by the PIs resulted in the formulation of the NSI method for system ID, combining local and global components to account for the sensitivity of strongly nonlinear systems to initial conditions and forcing. The PIs' final work, still ongoing, in conjunction with NextGen Aeronautics, Inc. and colleagues at Texas A&M University, will result in the design of an NES-based LCO suppression system housed in a winglet, specifically designed for the GTW. Upon completion of rehabilitation and modifications to the wing to accommodate the winglet/NES, the full system will be ready for additional testing in the TDT.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: None			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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Final Performance Report to AFOSR

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(DURIP 09): ACQUISITION OF A SCANNING LASER VIBROMETER SYSTEM FOR EXPERIMENTAL STUDIES ON NONPARAMETRIC NONLINEAR SYSTEM IDENTIFICATION AND AEROELASTIC INSTABILITY SUPPRESSION

Grant No.: AF FA9550-09-1-0455 (EQUIPMENT ONLY)
Grant Period: 01 June 09 – 31 May 10
Grant Monitor: Dr. David Stargel

Acquired Equipment: Scanning Laser Vibrometer (see below for details)

1. **Polytec Model PSV-400-H4 Turnkey 4-Channel High Performance, 80 kHz Bandwidth Vibrascan System and Model UHF-120 High Frequency Laser Doppler Vibrometer, with University Maintenance, Software Updates and Training ($354,566)**
2. **Dell T710 Server, 48 GB RAM, 2 X5560 Xeon Processors ($8,536)**

Executive Summary:

The PIs' current research and development, funded by AFOSR, aims to develop novel means of vibration control for aerospace systems, system identification procedures for strongly nonlinear dynamical systems, and a fully passive limit cycle oscillation (LCO) suppression system for a model generic transport wing (GTW) previously designed, built and tested in the TDT at NASA Langley. Initial efforts by the PIs led to the development of the Nonlinear Energy Sink (NES), a completely passive nonlinear mechanical device that, when physically attached to a vibrating primary system, draws energy from that system into itself in a one-way, irreversible fashion and effectively dissipates it. Later efforts by the PIs resulted in the formulation of the NSI method for system ID, combining local and global components to account for the sensitivity of strongly nonlinear systems to initial conditions and forcing. The PIs' final work, still ongoing, in conjunction with NextGen Aeronautics, Inc. and colleagues at Texas A&M University, will result in the design of an NES-based LCO suppression system housed in a winglet, specifically designed for the GTW. Upon completion of rehabilitation and modifications to the wing to accommodate the winglet/NES, the full system will be ready for additional testing in the TDT

Significant Work Accomplished:

The high-end computer provides an effective platform for simulations required to estimate the stability characteristics of the GTW, both with and without the NES-based LCO suppression system in order to evaluate performance. CFD code CAPTSDv has been extensively employed to obtain data needed for NES design, while UNS3D, a more sophisticated Reynolds-averaged Navier-Stokes code, has been used to verify and validate CAPTSDv results.

The laser vibrometer has, to date, been utilized during ground vibration testing (GVT) of the GTW at UIUC. Accurate, non-contacting velocity measurements were obtained at 40 locations over the surface of the GTW in its bare configuration, with an NES installed at the wing tip in lock-down, and with a fully functional NES in place, in order to verify that the strongly nonlinear behavior of the NES couples strongly to the second bending mode and first torsional mode of the wing. These modes were observed in prior analysis and testing and again in current simulations to cause the LCO. Selected results from the GVT are included in Figures 1 through 4, below.

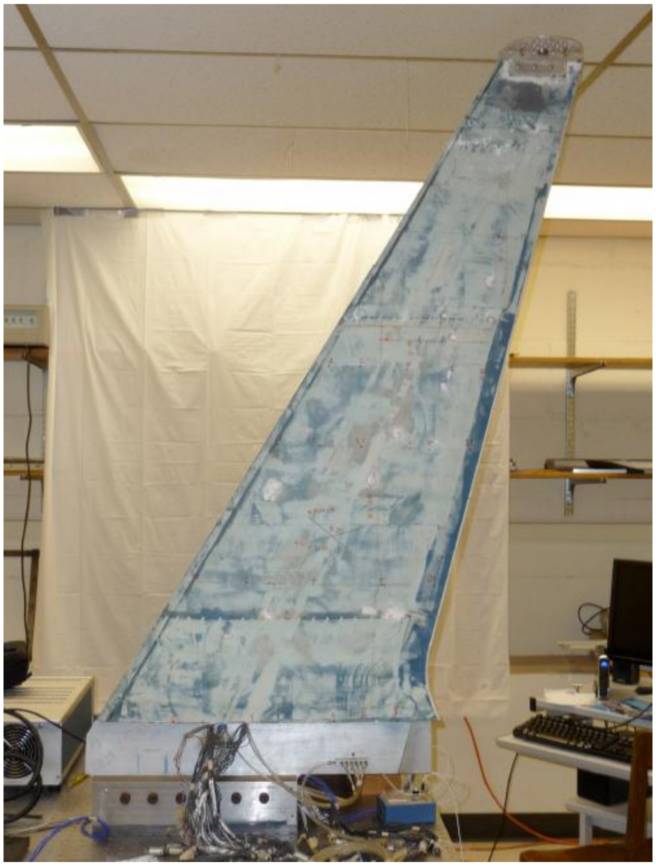

Figure 1: The GTW as obtained from NASA Langley on an optical table at UIUC, with NES installed on the wing tip in lock-down position, ready for ground vibration testing.

Figure 2: Photo showing shaker/stinger attachment to the GTW and wiring from internal sensors.

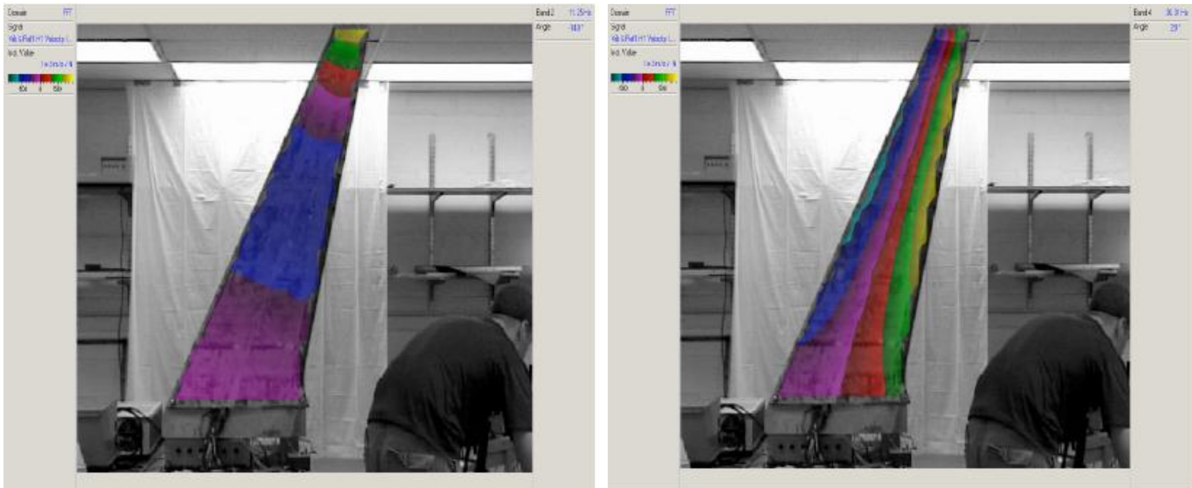

Figure 3: Mode shapes of GTW with NES in lock-down acquired with Polytec PSV-400 LDV. Left: 2^{nd} bending (11.25 Hz); right: 1^{st} torsion (30.31 Hz).

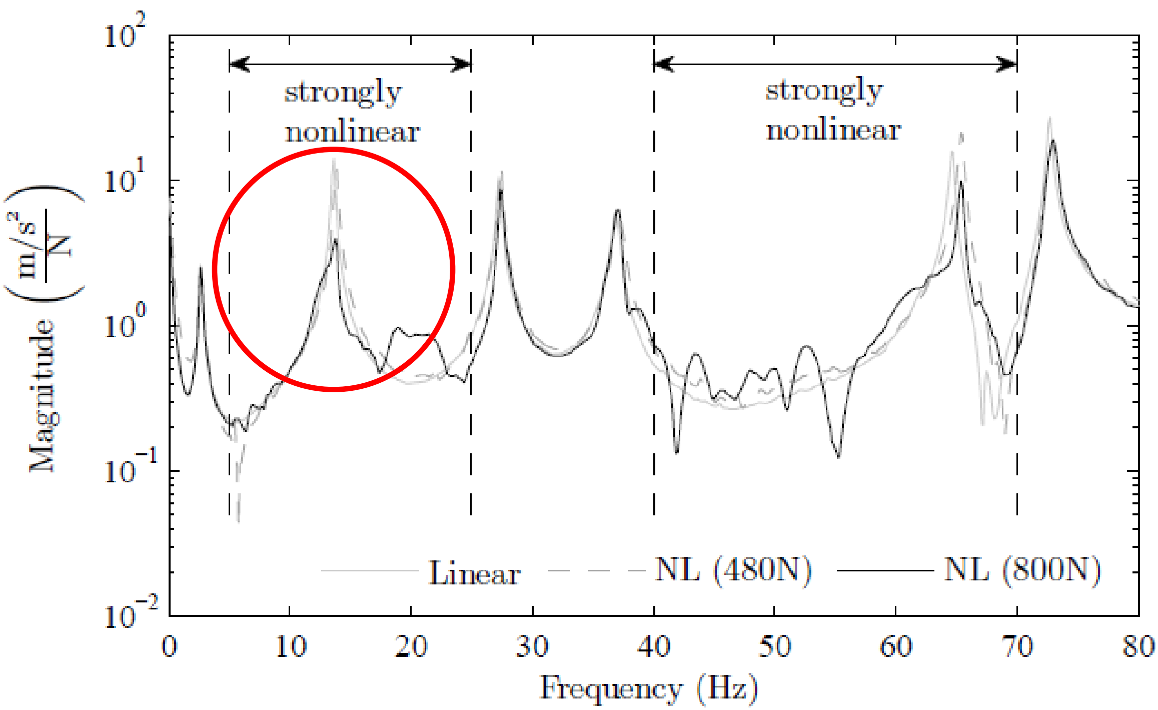

Figure 4: Accelerance frequency response functions obtained during GVT, comparing performance of GTW with NES under lock-down (linear), with NES in operating mode under moderate loading (NL 480N), and with NES in operating mode under peak loading (NL 800 N). Data acquired with Polytec PSV-400 LDV. Note the strong coupling of the NES with the second bending mode under peak loading (circled in red), resulting in nearly an order of magnitude of attenuation.